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ABSTRACT

The paper is a discussion of research on direct instruction and its implications for effective instruction in verbal math problem solving for elementary learning disabled students. Characteristics and problems of conventional programs are reviewed, as are the major features and logic of direct instruction programing. Components of instructional design are noted, including specification of objectives, identification of necessary preskills, and maintenance of acquired skills. The relationship of the direct instruction model to other promising models is analyzed, the feasibility of direct instruction in special education is considered, and obstacles to its implementation are noted. (Author/CL)

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Verbal Math Problem Solving: What the Research on Instruction Tells Us

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Abstract

This paper is a discussion of research on direct instruction and its implications for effective instruction in verbal math problem solving for LD students. Emphasis is to be given to a review of efficient methods of instruction and the following issues: time allocated for learning, instructional design, effecient presentation, practice and generalization. The compatibility of the direct instruction model and other models of teaching verbal math problem soving, and directions for future research are also discussed.

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Presentation Draft

It is generally recognized that a fundamental goal of math instruction at the elementary level is to provide students with the basic skills to solve quantitative problems in every day life, yet one of the most persistent problems is that many students do not learn to apply computational skills to verbally presented math problems. The results of the National Assessment of Educational Progress (1979) clearly indicate that many students fail to solve relatively simple verbal math problems, and most students cannot solve even moderately complex problems. The proportions of students with deficient skills in mathematical applications increased between 1973 and 1978. Silver and Thompson (1984) observed that in response to the difficulties that students have in solving verbal math problems, "the popular pedagogical literature is replete with articles suggesting the 'cure' for our problem solving ills" (p. 529). A simple 'cure' is probably unlikely, and there is a lack of consensus among many writers as to which procedures should be adopted, but there is a growing body of well conducted research studies that support the logic of basing instructional designs and procedures of verbal math problem-solving programs upon the principles of direct instruction. This paper is a discussion of those studies. It is not an exhaustive review of the math problem-solving literature. We will discuss six topics relevant to the implementation of the direct instruction model for teaching low achieving elementary students to solve verbal math problems including:

(a) characteristics and problems of conventional programs, (b) the major features and logic of direct instruction programming, (c) research on problem-solving that is related to issues and problems addressed and present in direct instruction programs for teaching problem solving skills, (d) the relationship of the direct instruction model to other models that show promise, and have the potential for complementing the direct instruction approach, (e) the feasibility of implementing direct instruction problem solving in special education and (f) directions for future research related to direct instruction of verbal math problem-solving.

Characteristics and Problems of Conventional Programs

About two years ago we became interested in studying the efficacy of direct instruction in verbal math problem-solving. We began, for purposes of comparison, with an attempt to summarize how the task of problem-solving is generally dealt with in major commercial programs. We observed that there was considerable variation between programs, thus, making it very difficult to easily describe a traditional approach in terms of such considerations as the types of activities provided, the degree of teacher-led instruction, the sequencing of preskills, formatting of lessons, or the like. We did find that four important shortcomings were present in virtually all of the programs. First, the directions provided to teachers were consistently vague. Since the manner in which the activities would be implemented is largely dependent upon the interpretation and discretion of the individual teachers, an almost infinite number of variations of instructional designs and procedures are possible. Second, minimal control is exerted over the types and sequences of problems used in

instruction. Although simple, readily-translated story problems were ubiquitous to commercial curricula, linguistically more complex problems, multi-step problems and problems with extraneous information were dealt with inconsistently. Third, instructional activities were often poorly designed, and frequently would allow correct responses to be made without the students' understanding of the tasks. Finally, insufficient amounts of practice were provided. Seldom were there ever indications given by the publisher as to the amounts of practice the teachers should provide.

Darch, Carnine and Gersten (1983) compared the effectiveness of direct instruction and a traditional set of procedures for teaching verbal math problem-solving to low achieving elementary students. An important obstacle to the implementation of their study was the identification of a set of procedures that were "traditional." Given the wide range of possible implementations of most instructional programs, it appears that there are many variations on the so-called traditional approach. They selected a four-step teaching strategy from Bolster, Cox, Gibb, Hansen, Kirkpatrick, Robitaille, Trimible, Vance, Walsch, & Wisner (1978), authors of the Scott-Foresman elementary math program. We reviewed the procedure and consider that it is not dramatically different from many procedures suggested by publishers of other major commercial math text programs. The student is required to: (a) write the numbers, (b) identify the correct operation, (c) write the complete number sentence, and (d) write the answer. The second step is the nut to crack. Bolster et al. (1978) recommend that the student be required to: (a) restate the problem in their own words, (b) identify the information that is given and

determine the information that is needed, (c) identify the question that is being asked in the problem and (d) identify the relevant and extraneous information. Failure to identify the correct operation independently would result in the teacher modeling how to choose the correct operation, discussing each conceivable operation with the students, and identifying the reasons why the alternative operations are not correct.

The problems with the Bolster et al. (1978) approach are representative of the deficiencies of many other recommended approaches to teaching problem-solving. First, the instructional guidelines are vague, thus, permitting many alternative interpretations and subsequent implementations of the procedures. Second, there is relatively little emphasis given to the selection and sequencing of instructional examples. This problem is not unusual. Common to most traditional approaches is the implicit assumption that all students learn differently. As a result, there is frequently greater emphasis given to attending to the individual interests and motivations of students than is given to instructional design. Given the considerable variation in linguistic complexity that exist in the presentation of verbal math problems, and the apparent effect that linguistic variation can have on the success of problem-solving efforts, it is important to control the content of instruction by carefully selecting and sequencing the types of examples presented. The third problem is that the correction procedures are apt to be inefficient. They are vaguely defined, apparently lengthy, and thus, likely to involve too much teacher-talk. Student errors should be anticipated and corrected in as concise and as matter-of-fact a manner as possible.

Vargas (1984) reported in her review a large number of commercial text programs, that inappropriate stimulus control was common in instructional materials designed to develop understanding. Thus, the students could solve many of the tasks without reading or comprehending the textual material, because irrelevant cues such as key words, grammar, pictures and layout were too frequently associated with the solutions. If students develop dependencies upon inappropriate or irrelevant cues, they will fail to solve problems in which those cues are either missing or present, but misleading. For example, Nesher (1976) and Wright (1968) found that students who depended upon key words made significantly more errors on problems which included key words as distractors that cued an inappropriate strategy or operation. Vargas (1984, p. 128) suggests that commercial programs should be more thoroughly reviewed.

> Few educators ferret out the variables controlling students as they respond to printed materials. Textbook publishers are concerned with the quality of the materials they publish, but fail to look at the relationship between what is on the page and the behavior of answering. Most companies conduct field tests of their instructional materials, ranging from questionnaires about how students "liked" the materials to analyses of completed exercises. Items which the students answer correctly (and/or "like") are left intact while items commonly missed are thrown out or revised. No analyses are made of the students' behavior while answering. No one asks, "To what is the student responding?" when they wrote a correct answer.

De Corte, Vershaffel and De Win (1985) stated that unfortunately textbook publishers apparently pay more attention to the arithmetic aspects of story problems than to the wordings of the problems. De Corte et al. (1985), p. 489) observed that children often fail to solve story problems, "not because they lack the necessary arithmetic skills, but because they do not succeed in constructing an appropriate problem representation due to their inability to understand correctly the condensed and sometimes ambiguous statement of the problem." Too often the values of exercises that were designed to increase understanding of verbal problem-solving are limited because inadequate attention to stimulus control and the importance of the different possible words of story problems.

The Direct Instruction Model

Direct instruction generally has been used to refer to behaviorally-based instructional activities that are directly related to increasing achievement in basic academic skills. Instructional procedures are considered to be 'direct' if the explicit purpose of the instructional activities is to increase academic achievement, and if instruction emphasizes teacher behaviors and variables related to classroom structure such as: small group instruction, teacher direction of learning, academic focus, high rates of correct responses, demonstration and prompting of correct responses, controlled practice, use of higher cognitive-level questions, group responding, independent practice, and feedback to student responses (Rosenshine, 1978, 1979; Stevens & Rosenshine, 1981).

The most explicitly described approach to direct instruction is the University of Oregon Direct Instruction Model. It was evaluated

in the national Follow Through Study and found to contribute significant gains in affect, achievement in basic academic skills and conceptual reasoning. Gersten (1985, p. 42) identified several features of the Oregon Direct Instruction Model that distinguish it from other behavioral approaches to instruction. Those features include:

> (a) the explicit teaching of 'general case' problem solving; (b) an emphasis on small group instruction as opposed to students working alone; (c) a systematic technology of correction procedures; (d) principles for cumulative review of previously learned material; and (e) insistence on mastery of each step in the learning process.

Unlike the more generic approaches to direct instruction (e.g., Good, Grouws, & Ebmeier, 1979; Rosenshine, 1978, 1979; Stevens & Rosenshine, 1981), which are basically independent of specific curricula and instructional designs, the Oregon Model places considerable emphasis on task demands and their presentation in the instructional sequence. Little emphasis is placed on the individual differences of learners. Instructional activities are based upon the careful selection and sequencing of instructional examples. Content variability is very tightly controlled.

General case programming, the basis for the development of direct instruction problem-solving strategies is a complex and rigorous process of instructional design. The first step is to examine the task and identify the range of problems of a particular class for which training must be provided. The exemplars with the most generally occurring sets of critical attributes would be introduced

earlier in training than more unusually occurring sets of attributes. The second step in the process is to develop a problem-solving strategy that has maximum generalizability across the range of possible variations of a particular task. Control must be maintained over relevant and irrelevant characteristics of stimuli presented during instruction in order to prevent the learning of misrules for problem-solving. General case programming is evaluated, and in that sense defined, in terms of the degree to which: (a) there is systematic control of stimuli and responses and (b) programming is efficient. Efficiency is judged in terms of the degree to which mastery is accomplished with the fewest possible trials and with the fewest possible errors, and (c) the problem-solving strategy is generalizable across tasks of a given class.

Direct Instruction of Verbal Math Problems

Silbert, Carnine and Stein (1981) identified eight aspects of instructional design that should be considered for efficient instruction in verbal math problem solving. They consider that careful consideration of these aspects will allow teachers to develop effective lessons and revise deficient commercial programs. The following discussion of Silbert et al.'s (1981) instructional design is a brief outline. You are encouraged to consult the text of Silbert and his colleagues for greater detail.

Specify objectives. Silbert et al. (1981) consider that students should be able to master verbally presented story problems--both written and oral presentations. Mastery is determined by successful demonstrations of acquisition and comprehension of content, and the performance of correct solutions to story problems of increasingly

greater grammatical, syntactic, and mathematical complexity.

Devise problem-solving strategies. The behaviorally-based direct instruction approach emphasizes the mastery of efficient generally useful strategies rather than the rote memorization of S-R chains. Once learned efficient strategies can be used outside training situations to solve a variety of examples of related problems, thus facilitating the generalization of problem-solving skills.

Silbert et al. (1981) examined the different types of story problems that children frequently encounter in elementary grades. They identified four basic types of addition and subtraction problems, and two types of multiplication and division problems. Addition and subtraction problems are classified as: simple action, classification, complex action and comparison problems. Multiplication and division problems can be classified as either problems that have key words to signal the operation or problems that do not have key words. Although the classification scheme developed by Silbert et al. (1981) is based upon logical analysis, research on problem-solving supports their observations (De Corte et al., 1985; Kilpatrick, 1969). Since some of those types of problems do not lend themselves to phrase-by-phrase translation into mathematical statements, Silbert et al. (1981) developed a general case problem-solving strategy that emphasizes the structure of the problems.

The strategy they recommend, "integrates knowledge of the fact family with basic language skills involving classification, comparison and verb knowledge. For example the numbers 2, 3, and 5 can be used to create four different types of addition and subtraction sentences.

Students are taught to use the "big number strategy" to determine whether the big number in the fact family is given in the problem. Once the students have been taught to use the strategy with all four basic operations, the process of applying the strategy is done in two steps. First, the child must determine whether the big number is given. Second, the child must determine whether one of the numbers is used over and over again.

Identify necessary preskills. The most immediately important preskill to learning the direct instruction problem-solving strategy is determining the missing number in the fact family when two of the three numbers are given.

Sequence skills. As with virtually all examples of direct instruction programming, the same general guidelines must be considered regarding the sequencing of skills: (a) preskills must be taught before the strategies are introduced, (b) easier skills are taught before the more difficult and complex skills, (c) strategies that are difficult or easily confused should not be introduced consecutively, (d) overt cognitive operations should be shaped to become more covert, and (e) the use of prompts should be faded at each level.

In the Silbert et al. (1981) approach to verbal math problem-solving the sequence of instructional activities is: (a) to introduce the simple action type of addition and subtraction story problems; (b) to teach students to use the fact family preskill in order to determine the missing number in the fact family; (c) apply the fact family strategy to more complex addition and subtraction story problems in the following order: classification, complex

action, and comparison problems. After students have mastered the addition and subtraction discrimination, multiplication problems with the key words "each" and "every" are introduced, followed by multiplication problems without key words. Division problems with the key words are introduced next, followed by division problems without key words. The instructional sequence should also include a systematically increased degree of complexity in the problems of each type and operation.

Maintenance of acquired skills. Mastery is acquired through massed practice during the acquisition stage of instruction and distributed practice during the maintenance stage.

Research on Approaches to the Design of Problem Solving Instruction

The rationale for the problem-solving strategy developed by Silbert et al. (1981) was based on logical analyses of the task of solving story problems, but research on verbal problem-solving provides a data-based rationale for: (a) their analysis of the problem-solving task, (b) the need for a generalizable strategy, and (c) the need for systematic control of the instructional activities and examples.

There have been many studies which have identified consistent relationships between variations in problem structure and the amount of difficulty that students have solving the problems (e.g., De Corte et al., 1985; Jerman & Mirman, 1974; Kilpatrick, 1969; Larsen, Parker, & Trenholme, 1978; Linville, 1976; Wheeler & McNutt, 1983; Wilson, 1967; Zimmerman, 1979). Two studies (De Corte et al., 1985; Zimmerman, 1979) investigated the effects of syntactic variations that result in different types of problems and the

difficulties that students have in solving those different types of problems.

Zimmerman (1979) and De Corte et al. (1985) observed that the structure of story problems would affect the degree to which students chose the correct operations. Zimmerman (1979) observed that students had more difficulty with story problems that were structurally different from the problems that preceded them, or were different from those recently presented in class. It appears that, left to their own devices the students tended to try to generalize strategies they had previously learned for solving problems of a given structure to problems of different structures. Frequently, their generalized strategies are limited and inappropriate.

De Corte et al. (1985) examined childrens' solutions to different types of story problems that correspond to three of different types of story problems in the classification proposed by Silbert et al. (1981)--simple action, complex action and comparison problems. They observed that: (a) children tend to develop different solution strategies to each of the different ways of wording the same quantitative problem; (b) ambiguities in the wordings of problems are related to higher proportions of incorrect solutions; and (c) by rewording the problems so as to remove some of the ambiguity had a positive effect on the solution processes of more than 50 percent of the students in the study. Clearly, the studies by Zimmerman (1979) and De Corte et al. (1985) support the position of Silbert et al. (1981) that the structures of verbal math problems have effect upon the accuracy of solutions devised by young children, because the strategies devised by young children tend to differ according to the

structurally different types that they are attempting to solve. The limited utility of some of the spontaneous student-generated strategies contributes to high error rates, because the strategies are frequently misapplied to story problems which are structurally different from the types of problems for which the given strategies are intended to be applied. De Corte et al. (1985) did not indicate whether the achievement level of students was related to their improvement (or failure to improve) when they were given the reworded and less ambiguous problems. It would be important to determine whether or not there is an interaction between the rewordings of problems and student aptitude. If the low achieving students did not perform better on the reworded problems, it would indicate that rewording problems is not a sufficient educational intervention for low achieving students. It may be necessary to combine the rewording tactic with carefully designed instruction in comprehension.

Studies on the effects of syntactic complexities and ambiguities on successful problem-solving have important implications for the design and sequencing of instructional programs. First, it appears that the introduction linguistic complexities and ambiguities should be carefully controlled. The simpler and more generally occurring structures should be introduced to the program earlier than more complex and more unusual structures. Second, general case strategy training will be needed by many children, particularly the less mature or slower learners, if they are expected to master the more complex or less routine problem structures.

It is generally recognized that much of the research on problem-solving instruction has been influenced by the work of

George Polya (1962, 1965, 1973). Polya's model involves six steps with checks: (a) read and reread the problem for understanding; (b) decide - what is asked for and what are the variables that are given; (c) determine what information is given and how it relates to the information that is unknown; (d) write the equations to express the quantitative relationships; (e) solve or compute; and (f) check by rerunning the process. Polya's self-conscious approach has been useful in suggesting procedures for organizing instruction for improving problem-solving skills, despite its deficiency as a description of actual problem-solving behavior (Silver & Thompson, 1984).

Bassler, Beers, and Richardson (1975) compared Polya's method with an alternative procedure that encourages the student to translate the information given in the story problem directly into an equation, rather than examine the problem as a whole before attempting to solve it. Bassler et al. (1975) observed that after training students to use the Polya approach, they were better able to choose the correct operations than the students trained to use the direct translation approach. The effects of training were apparent on a follow-up test four weeks after the initial period of instruction.

Blankenship and Lovitt (1976) used a set of procedures that are related to Polya's approach to improve the performances of seven boys in a remedial class on story problems in seatwork. Students were required to solve a set of story problems and have the seatwork checked by the teacher. Persistent errors resulted in the student being required to perform under increasingly more involved conditions. Under the first condition, the students were instructed to reread

their incorrect problems orally and to give the correct answers. If they reached criterion, they were given a more complex set of problems. If, however, a student failed to reach criterion, he was required to write out each incorrectly stated problem and to reanswer it. If the students reached criterion they advanced to the next class of problems, but if they failed to reach criterion on a class of problems they were required to: read each incorrect problem orally, provide a rationale for the operation that they chose, and offer an alternative solution. Blankenship and Lovitt (1976) found that their procedures were effective with all classes of problems except those with extraneous information. Although it is clear that the procedures were generally effective, it is not so clear that successes were due to either the increased involvement required by each of the successive conditions, or to the possibility that the more involved conditions that followed persistent errors functioned as negative reinforcers--that is the students worked more carefully under the less involved conditions in order to avoid the more involved conditions. There is no evidence in the description of the study to rule out the plausibility of the alternative explanation. It is also important to consider that Loritt and Blankenship's remedial students had previously developed problem-solving skills to the level that structured seatwork combined with consistent consequences would be adequate.

Wilson (1967) examined two approaches to specific training in problem-solving as well as a practice-only condition. He found that training students to examine the structure of the problem and to determine what information "is wanted" and what information "is given"

is a superior approach compared to either: (a) training students to examine the problem and to determine the sequence of events, and finally to summarize the action with an equation, or (b) simply allowing the students to practice solving story problems. There was not a significant difference between performances under the latter two conditions--neither of which resulted in significant amounts of improvement over time. Wilson (1967) concluded that:

> instruction in recognizing wanted-given structures in direct type problems facilitates the choice correct operation for indirect problems, prior to instruction on these types. On the other hand, the evidence also indicates that instruction in recognizing the action-sequence structures of direct problems inhibits the choice of correct operation for indirect problems (p. 496).

The instructional design proposed by Silbert et al. (1981) allows for the introduction of simple action problems prior to strategy training, but their strategy training is consistent with the suggestions by Wilson (1967). It is explicitly directed at recognizing the information that is given and determining the information that is needed.

Evaluations of Direct Instruction Problem-solving

Aspects of the instructional design for verbal math problem-solving as proposed in the Oregon model of direct instruction have been evaluated in two studies (Darch et al., 1983; Jones, Krouse, Feorene, & Saferstein, 1985).

Darch et al. (1982) evaluated the effectiveness of the direct instruction problem-solving strategy compared to the guided

instruction approach represented in the Scott Foresman program (Bolster, et al., 1978) for teaching low-achieving students to solve multiplication and division story problems. They found that: (a) significantly greater proportions of students in the direct instruction condition mastered the discrimination between multiplication and division story problems, as opposed to students in the traditional approach; (b) extended practice in the direct instruction condition had a significant effect upon the students' maintenance of their ability to choose the correct operations, but extended practice in the traditional approach, even though given in greater amounts than in the direct instruction condition, did not contribute to higher levels of achievement or maintenance than the limited practice for either program; and (c) many students, in the traditional program failed to perform at a satisfactory level after training--even when extended practice was provided. The study indicates that unless training takes place over a considerably longer period of time than was provided by Darch et al. (1983), it is unlikely that students who participate in programs that emphasize offering their own solutions and discussing their peers' solutions will improve dramatically in their ability to solve story problems. Darch et al. (1983) demonstrated that to be effective problem-solving instruction should: (a) present strategies that can be readily used with problems of different structures; (b) employ well-chosen examples; and (c) promptly correct student errors. They also demonstrated, as did Wilson (1967), that simply allowing students practice does not have a necessarily positive effect upon achievement.

Jones et al. (1985) compared the effects of sequenced versus concurrent training on the different types of verbal addition and subtraction problems described by Silbert et al. (1981). The third grade students were selected on the basis of their poor performance on a pretest on verbal math problems. Both training conditions were based upon the procedures of direct instruction as described by Silbert et al. (1981), but the orders in which the training examples were presented differed between the training conditions. In the sequential condition the examples were presented in the following order: simple action, classification, complex action, and comparison problems. In the concurrent training condition the simple action problems were also presented before the other types of problems, but the three remaining types of problems were not separated for either preskill or problem-solving instruction. Jones et al. (in press) observed that students in the sequential training condition made significantly greater progress than students in the concurrent condition. Students in the concurrent condition did not improve their skills in selecting the correct operation. These results are consistent with the observations by De Corte et al. (1985). It appears that attending to the linguistic structure of the problems has a predictable effect upon achievement. The study by Jones et al. (1985) further demonstrates that linguistic structure should be considered in the sequencing of instructional examples and not merely in the selection of the instructional examples. There are several explanations for the contribution of the sequential arrangement of different types of problems to higher achievement. First, the presentation of problems of the same type provides the opportunity for

repeated responding to similar relevant attributes. The repetition would be expected to increase the probability that students recognize and respond to the relevant attributes of the problems. Second, the sequential procedure may have been easier for the students to follow. Although the Silbert et al. (1981) fact family strategy is generalizable across the four types of problems, concurrent presentation condition requires some variations in the teaching formats from problem-to-problem. Although outright confusion of the students as a result of inept presentations by the teacher was not a factor in the concurrent condition of this study, confusion would be very likely outside controlled experimental situation. A third possible advantage of sequential training is consistent with Wilson's (1967) conclusion that skills developed on problems of one structure facilitate the learning of problems of a different structure that are subsequently presented.

In summary, the evaluations of direct instruction of verbal problem-solving by Darch et al. (1983) and Jones et al. (1985) demonstrate that explicit, well controlled presentations, of carefully selected and sequenced examples contribute to higher levels of student achievement with fewer trials and in less time. These studies also suggest that simply allowing low-achieving students to practice solving story problems will not be sufficient for improving their performance.

Directions for Future Research on Direct Instruction and Problem-solving

Considerably more research on the application of direct instruction procedures to verbal math problem-solving needs to be

done. Several directions for future research will be discussed including: (a) teaching students to deal with extraneous information; (b) increasing the probability that skills will generalize to solve problems that are presented under different stimulus conditions and be maintained over time; (c) identifying obstacles to the implementation of the direct instruction model in special education programs; (d) assessing the compatability of the direct instruction approach with other models of instruction.

Extraneous information. Several studies have reported that story problems with extraneous verbal or quantitative information can be extremely difficult for children to solve successfully (Arter & Clinton, 1974; Blankenship & Lovitt, 1976; Carpenter, Corbitt, Lindquist, & Reys, 1980; Carpenter, Matthews, Lindquist & Silver, 1984). The guidelines provided by Silbert et al. (1981) acknowledge the importance of teaching students to desl efficiently with extraneous verbal and quantitative information. Unfortunately the formats for teaching those solution skills have not been explicitly defined. Research on the application of the direct instruction model to the persistent problem of coping with distractors must begin with: (a) an examination of the important variables which should be considered for the selection of instructional examples; (b) the development of explicit instructional formats for teaching students nonconfusing general case problem-solving strategies for coping with the extraneous information; and (c) evaluation studies should be conducted to determine the most efficient strategies. Care must be taken to assure that the strategies are generalizable. The strategies should facilitate the successful solution of problems with different

types of extraneous information and/or multiple operations, but not confuse the solution strategy learned earlier for solving the simpler forms of story problems. At present the success of the Silbert et al. (1981) approach depends upon their sequencing skills in the problem-solving hierarchy. Insufficient research has been done to determine the effectiveness of the Silbert et al. (1981) approach to coping with extraneous information in problem solving to warrant great confidence that their procedure will dramatically reduce the difficulty of coping with extraneous information. The research on the implementation of less explicit approaches to instruction indicates that extraneous information and multiple operations present significant and relatively intractable difficulties.

Generalization. A basic principle of the direct instruction is that the greatest amount of content must be taught in the time allocated for instruction. That principle necessarily must be translated into teaching practices and instructional designs that will allow for mastery of skills to be acquired within the fewest number of trials possible. Such programming requires that the procedures provide a basis for generalization--predictable, controlled, and to the greatest extent possible, errorless generalizations--within as few trials as possible. It is very likely that within the approach to verbal math problem-solving articulated by Silbert et al. (1981), there will be room for refinement. The purpose for those refinements will almost certainly be to improve the efficiency of the generalization of skills learned from instruction on the selected set of exemplars. Research should be conducted to: (a) improve the set of training examples, (b) determine the optimal sequence in which to

present the problems of different structures, and (c) develop strategies for solving the more complex and difficult problems discussed earlier that will not be incongruent with the strategies used to solve the simpler and more directly stated problems.

The process of improvement will likely proceed according to three of the techniques for programming generalization described by Stokes and Baer (1977). That is, changes will be based upon: (a) sequential modifications of the procedures and instructional design, (b) selections of exemplars that are sufficient in number and representative with regard to stimulus characteristics, and (c) refinements of verbally mediational strategies. With regard to the development of verbal mediation strategies, concern may be expressed that the strategies learned in the remedial conditions will not transfer to the less controlled regular classroom or to everyday settings (Anderson-Inman, Paine, & Deutchman, 1984). Research should be conducted to determine whether or not students use the strategies that they have learned, or even if the use of the strategies is necessary. The concern expressed by Anderson-Inman et al. (1984) was based upon measures of neatness on seatwork; a behavior that may well differ significantly with regard to the conditions by which it is maintained from a cognitive problem-solving skill. Neatness could well be described as a perceptual-motor task that is unlikely to be maintained according to any given criteria unless it is differentially reinforced according to that criteria as opposed to other criteria. Mastery of verbal problem-solving skills, on the other hand, is based upon knowledge of linguistic comparisons, classifications and verbs. Once that knowledge has been acquired, it may not be necessary for the

child to verbalize the originally stated strategy. For the child who has acquired understanding of the verbal structure of story problems, the only response that will be reinforced will be the accuracy of the performance, not the performance of a process such as neatness that: (a) is defined in terms of some specifiable set of criteria which will probably vary from one setting to another, (b) is generally maintained through external reinforcement, and (c) only selectively maintained through self-control--especially by children. The problem of generalization of training in verbal problem solving is under researched. While we may speculate about the implications of research on the effects of direct instruction on other behaviors, we are obviously limited by the generalizability of those results.

Feasibility of direct instruction in special education. Much of the research documentation for the greater effectiveness of direct instruction, compared to less structured and traditional approaches, has been provided from studies of the performances of low-achieving students from regular classrooms. A few evaluations of direct instruction have been done with special education samples, and those studies are consistent with the studies of low achieving regular class students (for a review see Gersten, 1985). Thus, it appears that the greater effectiveness of direct instruction compared to more traditional approaches to verbal problem-solving would be observed in the special education as well as compensatory education settings.

The obstacles to the extensive implementation of instructional programs are frequently not related to the effectiveness. Wolf (1978, p. 206) in his discussion of the social validity of treatments stated that:

> If the participants don't like the treatment then they may try to avoid it, or run away, or complain loudly. And thus society will be less likely to use our technology, no matter how potentially effective it might be.

There is substantial documentation for the effectiveness of direct instruction, but the model is by no means enjoying tremendous popularity. There are several possible reasons why the direct instruction model is not widely accepted or used. First, teachers generally operate on the basis of personal discretion. Although state departments of education and districts establish curriculum guides and standards, the decisions as to how and when a skill will be taught is generally left up to the individual teachers. Teachers who have not used the direct instruction approach have tended to resist its implementation because they perceive that it was inflexible and did not allow for the teacher to be creative in their instruction (Gersten & Guskey, 1985). Flexibility and creativity are two traits most frequently cited by teachers and teacher trainees as being important for effective teaching, but the research shows quite clearly that loosely structured programs are less effective than the more highly structured and well designed programs. Furthermore, in a large scale evaluation of instruction in second and third grade classrooms conducted by Baker, Herman and Yeh (1981), it was found that the use of diverse instructional resources (e.g., puzzles, learning games, or audio-visual aides) were associated with decrements in achievement in reading and mathematics. Although creative and unusual approaches are used to vary the instructional routine, there is evidence that they are seldom used to address instructional problems directly, therefore,

it is not surprising that the variations have not accounted for improved achievement.

A second obstacle to the acceptance of the direct instruction model is the relatively low emphasis that is given to the importance of individual differences compared to the emphasis given to instructional design. The results of the Follow Through study, however, clearly indicate that the direct instruction approach contributed to much higher levels of achievement than programs that placed a great emphasis on individual differences. In the direct instruction model individual differences are defined in terms of the child's entry level into the instructional sequence. The instructional sequence, in turn, is defined in terms of the skills being taught, not the persons who are being taught (Becker & Carnine, 1981). This obstacle will probably be one of the most difficult obstacles to overcome. The myth that individual differences are of major importance in determining appropriate programs of instruction will probably die very hard.

A third obstacle to the implementation of direct instruction would be the problem of providing the teachers with adequate training and supervision. One of the primary rules for the implementation of direct instruction programs is the provision of appropriate training and careful supervision of teachers in the use of the procedures. Although the approach appears to be very simple, the principles that underlie the procedures are derived from a detailed and complex theory of instruction. Inadequately trained teachers make program modifications that would violate basic principles of the procedure. Thus, the procedure that they implement may not be an example of

direct instruction, if previous research is a valid predictor, their program will not be as effective as it might have been. If direct instruction programs fail to produce the expected results it is unlikely that the model will be accepted. On the other hand, where direct instruction has apparently made major contributions to student achievement, teachers have shown greater commitment to the approach despite strong initial resistance (Gersten & Gusky, 1985).

A fourth obstacle to the effective implementation to the application of direct instruction procedures for teaching of verbal math problem-solving would be the amount of teacher time that would be required to prepare the instructional activities. Brown (1985) stated that teachers would require considerable training in order to do an adequate job of "fleshing out" the guidelines presented by Silbert et al. (1981). She is probably correct, but it is a basic 'given' that teachers must have an adequate curriculum as the basis for their program. One should not expect that even trained teachers must expend their limited resources of time and energy "fleshing out" the guidelines proposed in Silbert et al. (1981). That text is a reference, and is very valuable for presenting a detailed description of the application of direct instruction to the teaching of elementary level mathematics. Although teachers frequently find it is a useful guide for modifying or salvaging programs that are less explicitly controlled, it is not reasonable to expect that teachers should develop integrated curricula. They are primarily presenters and managers. Although they are generally able to master the presentation of direct instruction some teachers are not able to adequately develop new concepts for instruction (Good et al., 1983). The responsibility

for developing high quality curricula rests with text publishers. It is the responsibility of teachers and curriculum specialists to carefully evaluate instructional programs before adoption, not to write them.

Persons interested in examining the direct instruction model as it applies to verbal problem solving should consult the following sources: Direct Instruction Mathematics, Corrective Mathematics, or DISTAR Arithmetic. We recommend Direct Instruction Mathematics as a reference because it provides the rationale for instructional activities and procedures. Corrective Mathematics is the remedial program. DISTAR Arithmetic is the program that was originally developed as a developmental program for disadvantaged students in compensatory education programs. The DISTAR program is apt to be too pedestrian for many LD students in remedial elementary programs. The combination of Direct Instruction Mathematics as the reference and Corrective Mathematics as the curriculum would be a good combination for use in remedial programs. We suggest that teachers consider adopting the Corrective Mathematics curriculum, and use the Silbert et al. (1981) text as a reference to guide the development of additional instructional examples and activities that may be needed in the remedial and special education context.

Compatibility of direct instruction with other models of instruction. In their preface to Direct Instruction Mathematics, Silbert et al. (1981) acknowledge that their approach is not a panacea. Improvements and refinements are possible, expected and needed. One likely avenue for improvements is through the incorporation of the direct instruction procedures with compatible

procedures from other models. A word of caution is in order. The combination of models should be based upon a rational interpretation of instructional theory, and not upon an eclectic hodge-podge combination. There are three models that may complement the direct instruction approach to verbal math problem solving: (a) Cawley Interactive Model, (b) cooperative learning and (c) data-based instruction.

Cawley's Interactive Model (see Cawley, Fitzmaurice, Shaw, Kahan, & Bates, 1978, 1979a, 1979b) is the basis for Project Math. In the interactive model the greatest emphasis is placed upon the application of basic skills to the solution of everyday quantitative problems, and the manipulation of the modes for presentation of and response to verbal problems. To present a problem the teacher may: (a) construct a problem with concrete manipulatives; (b) present a picture or prearranged set of things; (c) verbally present the problem; or (d) write the problem. To respond the student may respond in any of the four modes identified for presentation. Thus, the interactive mode allows for 32 different possible combinations of presentation and responding. The opportunities for meaningful manipulations and flexibility are stressed as advantages of the interactive model.

The interactive model shares several important assumptions with the direct instruction model: (a) the sequence of skills is critical to successful learning; (b) instruction is most effective when practice and responding are overt; (c) teacher direction and monitoring of instruction are essential; (c) the complexity of task demands must be carefully controlled; and (d) what is not taught is not apt to be learned. While the interactive model shares important

basic assumptions with direct instruction, its implementation should be carefully monitored to be sure that instruction is as efficient as possible. There is the possibility that the extra flexibility that the interactive approach allows for is paid for with an actual loss of control. In such a case the teacher may be required to spend a great deal of time and energy to plan and to control; the instructional sequence and presentation of examples. The interactive approach seems to be best suited for the secondary level remedial program.

The effectiveness of cooperative learning has recently been demonstrated to have wide application (Slavin, 1983). Cooperative learning programs involve the arrangement of students into four member teams that are heterogeneous with respect to aptitude. The teams are rewarded on the basis of the average team performance, thereby providing an incentive for students to help one another to master academic objectives. Slavin and Karweit (1984) compared the effectiveness of cooperative learning and direct instruction and observed significantly higher achievement in the cooperative learning groups regardless of whether or not students were provided mastery training. Caution should be maintained in interpreting the results of this study. Most studies of mastery learning have involved elementary level students. The students in the Slavin and Karweit (1984) study were low achieving ninth graders. Failure of ninth grade students may occur for a number of motivational reasons that might out-weigh the instances of failure due to never having acquired the skill. In such a case the students' greater responsiveness to the interdependent group contingencies of the cooperative learning condition as opposed to the instructional design would be expected. Cooperative learning

has an obvious and important contribution to the direct instruction program. It will allow the teacher to provide instruction to more students within the same amount of time, and it has been associated with higher levels of social acceptance of exceptional children.

Precision teaching or data-based instruction is another approach that is compatible with the direct instruction approach. Both approaches are grounded in the logic of behavioral learning theory. White (1977) contends that procedures are complimentary. Maintaining daily assessments of student performance would give teachers greater precision in their evaluation of the effectiveness of instruction, and thereby, provide greater control over instruction. In a recently completed study of the training of student teachers, Jones and Krouse (1985) observed that student teachers who used precision teaching and direct instruction methodologies obtained higher levels of achievement from their LD students than student teachers who were not required to use either the precision teaching techniques or direct instruction.

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References

Anderson-Inman, L., Paine, S.C., & Deutchman, L. (1984). Neatness counts: Effects of direct instruction and self-monitoring on the transfer of neat-paper skills to nontraining settings. Analysis and Intervention in Developmental Disabilities, 4, 137-155.

Arter, J. A., & Clinton, L. (1974). Time and error consequences of irrelevant data and question placement in arithmetic word problems, II: Fourth graders. Journal of Educational Research, 68, 28-31.

Baker, E. L., Herman, J. L., & Yeh, J. P. (1981). Fun and games: Their contribution to basic skills instruction in elementary school. American Educational Research Journal, 18, 83-92.

Bassler, O. C., Beers, M. I., & Richardson, L. I. (1975). Comparison of two instructional strategies for teaching the solution of verbal problems. Journal for Research in Mathematics Education, 6, 170-177.

Becker, W. C., & Carnine, D. W. (1981). Direct instruction: A behavior theory model for comprehensive educational intervention with the disadvantaged. In S. W. Bijou & R. Ruiz (Eds.), Behavior modification: Contributions to education (pp. 145-210). Hillsdale, NJ: Lawrence Erlbaum Associates.

Blankenship, C. S., & Lovitt, T. C. (1976). Story problems: Merely confusing or downright befuddling? Journal for Research in Mathematics Education, 7, 290-298.

Bolster, L., Cox, G., Gibb, E., Hansen, V., Kirkpatrick, J., Robitaille, D., Trimible, H., Vance, I., Walch, R., & Wisner, R. (1978). Mathematics around us: Skills and applications. Glenville, IL: Scott Foresman.

Brown, V. L. (1985). Direct instruction mathematics: A framework for instructional accountability. Remedial and Special Education, 6, 53-58.

Carpenter, T. P., Corbitt, M. K., Kepner, H. S., Jr., Lindquist, M. M., & Reys, R. E. (1980). Solving verbal problems: Results and implications from the national assessment. Arithmetic Teacher, 28, 8-12.

Carpenter, T. P., Matthews, W., Lindquist, M. M., & Silver, E. A. (1984). Achievement in mathematics. Results from the national assessment. Elementary School Journal, 84, 485-495.

Cawley, J. F., Fitzmaurice, A. M., Shaw, R. A., Kahn, H., & Bates, III, H. (1978). Mathematics and learning disabled youth: The upper grade levels. Learning Disabilities Quarterly, 1, 37-52.

Cawley, J. F., Fitzmaurice, A. M., Shaw, R., Kahn, H., & Bates III, H. (1979a). LD youth and mathematics: A review of characteristics. Learning Disabilities Quarterly, 2, 29-44.

Cawley, J. F., Fitzmaurice, A. M., Shaw, R. A., Kahn, H., & Bates III, H. (1979b). Math word problems: Suggestions for LD students. Learning Disabilities Quarterly, 2, 25-40.

Cawley, J. F., Goodstein, H. A., Fitzmaurice, A. M., Lepore, A. V., Sedlak, R., & Althaus, V. (1976-77). Project MATH, Levels I, II, III and IV. Tulsa: Educational Development Corporation.

Darch, C., Carnine, D., & Gersten, R. (1983). An evaluation and analysis of a direct instruction approach to teaching math problem solving. Paper presented at the annual conference of the American Educational Research Association, Montreal.

De Corte, E., Verschaffel, L., & DeWin, L. (1985). Influence of rewording verbal problems on children's problem representations and solutions. Journal of Educational Psychology, 77, 460-470.

Engelmann, S., & Carnine, D. (1981). Corrective Mathematics. Chicago: Science Research Associates.

Engelmann, S., & Bruner, E. (1975). DISTAR Arithmetic. Chicago: Science Research Associates.

Gersten, R. (1985). Direct instruction with special education students: A review of evaluation research. Journal of Special Education, 19, 41-58.

Gersten, R., & Guskey, T. R. (1985). Transforming teacher reluctance to teacher commitment. Paper presented at annual conference of American Educational Research Association, Chicago.

Good, T., Grouns, D., & Ebmeir, H. (1983). Active mathematics teaching. New York: Longman.

Jerman, M. E., & Mirman, S. (1974). Linguistic and computational variables in problem solving in elementary mathematics. Educational Studies in Mathematics, 5, 317-362.

Jones, E. D., Krouse, J. P., Feorene, D., & Saferstein, C. A. (1985). A comparison of concurrent and sequential instruction of four types of verbal math problems. Remedial and Special Education, 6, (5), 25-31.

Jones, E. D., & Krouse, J. P. (1985). Unpublished data.

Kilpatrick, J. (1969). Problem solving in mathematics. Review of Educational Research, 39, 523-534.

Larsen, S. C., Parker, R. M., & Trenholme, B. (1978). The effects of syntactic complexity upon arithmetic performance. Learning Disability Quarterly, 1, 80-85.

Linville, W. J. (1976). Syntax vocabulary, and the verbal arithmetic problem. School Science and Mathematics, 76, 152-157.

National Assessment of Educational Progress, Mathematical applications (Report 09-MA-03). Denver: NAEP, 1979.

Nesher, P. (1976). Three determinants of difficulty in verbal arithmetic problems. Educational Studies in Mathematics, 7, 369-388.

Polya, G. (1965). Mathematical discovery: On understanding, learning and teaching problem solving, Vol. 1. New York: Wiley.

Polya, G. (1965). Mathematical discovery: On understanding, learning and teaching problem solving, Vol. 2. New York: Wiley.

Polya, G. (1973). How to solve it (3rd ed.). Princeton, NJ: Princeton University Press.

Rosenshine, B. (1978). Instructional principles in direct instruction. Paper presented at annual meeting of the American Educational Research Association, Toronto. ED 155 152.

Rosenshine, B. V. (1979). Content, time and direct instruction. In P. L. Peterson and H. J. Walberg (Eds.), Research on teaching: Concepts, findings and implications. Berkeley: McCutchan.

Silbert, J., Carnine, D., & Stein, M. (1981). Direct instruction mathematics. Columbus, OH: Charles E. Merrill.

Silver, E. A., & Thompson, A. G. (1984). Research perspectives on problem solving in elementary school mathematics. The Elementary School Journal, 84, 529-545.

Slavin, R. E. (1983). Cooperative learning. New York: Longman.

Slavin, R. E., & Karweit, N. L. (1984). Mastery learning and student teams: A factorial experiment in urban general mathematics classes. American Educational Research Journal, 21, 725-736.

Stevens, R., & Rosenshine, B. (1981). Advances in research on teaching. Exceptional Education Quarterly, 2, 1-9.

Stokes, T. F., & Baer, D. M. (1977). An implicit technology of generalization. Journal of Applied Behavior Analysis, 10, 349-367.

Vargas, J. S. (1984). What are your exercises teaching? An analysis of stimulus control in instructional materials. In W. L. Heward, T. E. Heron, D. S. Hill, & J. Trap-Porter. Focus on behavior analysis in education (pp. 126-141). Columbus, OH: Charles E. Merrill.

Wheeler, L. J., & McNutt, G. (1983). The effect of syntax on low-achieving students' abilities to solve mathematical word problems. Journal of Special Education, 17, 309-315.

Wilson, J. W. (1967). The role of structure in verbal problem solving. The Arithmetic Teacher, __, 486-497.

White, O. R. (1977). Behaviorism in special education: An arena for debate. In R. D. Kneedler and S. G. Tarrer (Eds.). Changing perspectives in special education (pp. 62-82). Columbus, OH: Charles E. Merrill.

Wolf, M. M. (1978). Social validity: A case for subjective validity. Journal of Applied Behavior Analysis, 11, 203-214.

Wright, J. P. (1968). A study of children's performance on verbally stated problems containing word clues and omitting them. Dissertation Abstracts, 29, 1770B.

Zimmerman, C. W. (1979). Contextual details and mathematical problem difficulty. Dissertation Abstracts International, 40, 143A.

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